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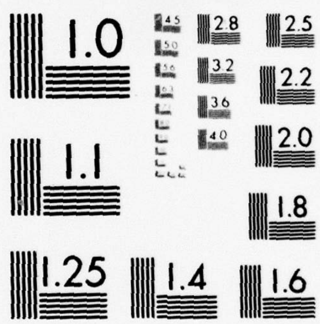

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AN OVERVIEW OF AVIONICS TECHNOLOGIES FOR THE IMPROVEMENT OF ALL WEATHER ATTACK AVIONICS SYSTEM (AWAAS) OPERATIONAL READINESS IN THE 1980-1990 TIME FRAME.

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PREFACE

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ABSTRACT

A broad assessment is made of the technological development required to improve the overall readiness of all weather attack avionic systems to be developed in the 1980-1990 time frame. The projected state-of-the-art in the post-1980 time frame is briefly outlined and the additional development required to achieve significant improvements in system readiness is summarized. Areas of technological risk are identified. Required development and anticipated risks in the following areas are described:

Electro-optical and Infrared Systems
Radar Systems
Conformal Array Antennas
Display Systems
Interior Data Transmission Systems
Data Links
Computers and Microprocessors

Software
Microelectronics
Microwave Integrated Circuitry and Surface Acoustic
Wave Devices
Standard Avionics Modules
BIT/BITE/Designed-in Testability
Navigation Systems
Aircraft Electrical Power Systems

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I. INTRODUCTION

This report addresses some of the principal System Readiness issues which will almost certainly be encountered in the development of an all weather attack avionics system (AWAAS) in the 1980-1990 time frame. Since a specific airframe cannot be identified at this time, airframe issues are not included, except where general references to the airframe are necessary in discussions of other issues.

The implementation of an AWAAS will be governed by the state-of-the art in avionics technology that will exist in the post-1980 time frame. In this report, the state-of-the-art is summarized in terms of technological capabilities that are anticipated to exist in the early 1980's in certain selected technology risk areas. These technology areas are:

- Electro-Optical and Infrared Systems
- Radar Systems
- Conformal Array Antennas
- Display Systems
- Interior Data Transmission Systems
- Data Links
- Computers and Microprocessors
- Software
- Microelectronics
- Microwave Integrated Circuitry and Surface Acoustic Wave Devices
- Standard Avionics Modules
- BIT/BITE/Designed-in Testability
- Navigation Systems
- Aircraft Electrical Power Systems

This list is not all-inclusive, but it does contain most of those areas in which AWAAS development risks and system readiness problems are likely to be encountered.

Because of the large number of technology areas that are addressed, only a brief discussion of each area will be given, including a projection of the anticipated state-of-the-art in the post-1980 time frame, and a discussion of risk areas and their potential effects on system readiness.

II. SYSTEM READINESS TECHNOLOGY RISK AREAS

A. ELECTRO-OPTICAL AND INFRARED SYSTEMS

This section contains discussions of potential reliability and maintainability issues in:

Imaging Infrared Systems,
Laser Designators,
Low Light Level Television (LLLTV), and
EO Countermeasures

Primary stress has been placed on the probable evolution of Forward-Looking Imaging IR (FLIR) systems. This is because of the apparent preference for FLIR's as opposed to LLLTV systems, for attack aircraft (witness the A-6E TRAM (Target Recognition/Attack Multisensor) and A-7E TRAM). This trend toward the use of FLIR's has continued even though CCD's (Charge Coupled Devices) for LLTV's are a current technology, while the detector materials and processing substrates for IR mosaics have not yet been fully developed.

1. Imaging Infrared Systems

The reliability and maintainability assessment of current FLIR's is in the initial stages because of the limited number of operational systems. Even so, the present systems show reliability which is poor in relation to other equipment of similar complexity, but which are more highly developed. Anticipated design evolution and increased use of common modules are likely to improve this situation. However, the degree of improvement is difficult to predict. Specific areas of difficulty include:

a. The usual array of problems associated with heavy turrets and gimbals,

b. Difficult optical alignments when optical elements are replaced,

c. Packaging requirements which result in high component density, making component replacement difficult,

d. Fault isolation at the organizational (O) level depends heavily on visual interpretation to augment Built-In Test (BIT),

e. Some systems require intermediate (I) level shops to have high vacuum capability,

f. Some systems require liquid nitrogen or helium for cooling,

g. Due to the sensitivity of IR optics to temperature variations, air conditioning and/or heating units are required on many systems to maintain optical focus, and

h. Efforts to develop and use "Common FLIR Modules" must be coordinated with all users.

Cooling to about $70^{\circ}K$ is presently required to maintain the sensitivity of the detectors. Research is ongoing to find materials which are sufficiently sensitive at higher temperatures (at about $200^{\circ}K$). These detectors will require cooling, but thermoelectric coolers should be adequate in these applications.

Advancing technology is concentrating on miniaturization by the elimination of mechanical scanning in the imaging process. The elimination of mechanical scanning to generate an IR image may be accomplished in two steps. Initially, one dimension of scanning (typically horizontal scanning) may be eliminated; finally, a totally staring system may be developed. The initial system may consist of a 6 to 10 by 300 to 500 element array of detectors located in the focal plane of the optics and mechanically scanned in the other (vertical) direction. The 300 to 500 element horizontal readout may require a single preamplifier instead of the present amplifier per detector. The exact number of elements will be related to the desired display bandwidth. The 6 to 10 elements in the vertical dimension may be time delay integrated to achieve higher sensitivity and reduce detector uniformity requirements.

The complete elimination of mecahnical scanning (a staring system) may be achieved by incorporating an array of detectors in the focal plane of the optics (also referred to as a "Mosaic Array"). To match present display formats and to achieve comparable resolution, these arrays would require 300 by 300 to 500 by 500 elements. It is presently possible either to mount detectors on a substrate (hybrid arrays) or to form a single material into a detector array (monolithic arrays).

a. Hybrid Arrays

The sensor, preamplifier and signal processors are separate materials so that each can be tailored for best operation. Cooling is easier but problems arise in that bonding or connecting the dissimilar materials may introduce manufacturing difficulty.

b. Monolithic Arrays

The sensor, preamplifier, and signal processor are of the same material. This technology has the advantage of simplicity of fabrication but is restrictive in the choice of materials. If some silicon dopings are used, cooling to 25°K or less may be required. Other silicon dopings are under investigation but have not resulted in a certainty that they will be useful. If some other monolithic material is to be used, such as indium antimonide, much work will be necessary before it can be developed to the quality of silicon as a CCD or as a preamplifier substrate.

Two primary methods of transferring and reading out detector charge have been investigated; these include charge coupled and charge injection devices (CCD and CID). Presently, only small numbers of detectors have been mounted to form IR arrays. A way of reliably constructing and reading out a large array with the required temperature range and sensitivity has not been determined. To avoid detector saturation, a system of this size would require prohibitively high readout rates (perhaps 1000 frames/second). It is possible that a system of "subarrays" 32 by 32 to 64 by 64 elements each will be constructed into a large mosaic, with each subarray independently read out. Some of the problems associated with the development of IR mosaic arrays are:

a. Detector Uniformity

A way to obtain uniform detectors to within 1% or less needs to be developed. Alternately, a way to compensate for non-uniform detectors is required.

b. Saturation

To avoid saturation, independently read out subarrays may be used.

c. Clocking Problem

A trade-off between high capacitance detectors to counter saturation and low capacitance detectors for high speed readout must be made.

d. Lithographic Techniques

Lithographic techniques must be developed to deal with different materials and to reliably construct arrays with a large number of small detectors. The detector density must also be increased so that the total array is of reasonable size.

It is thus anticipated that miniaturization by elimination of scanning to obtain an IR image and the use of new detector materials operating at higher temperatures will resolve some of the reliability and maintainability problems of present systems.

2. Laser Designators

The main problems associated with current lasers are due to cooling and safety requirements. Some lasers require nitrogen at high pressure (300 PSI) for cooling. These systems are subject to leakage, require purge capability and desiccants to remove moisture. Laser checkout presents a safety problem to maintenance personnel.

Advancing technology is not concerned with either of these problems but concentrates in the areas of miniaturization, power increase, new operating frequencies and coding. Power increases will undoubtedly contribute to continued cooling problems unless major advances in efficiency are obtained. Laser coding and decoding will potentially add new maintenance problems which are, at present, undefined. Finally, new technology may use CO_2 lasers operating at 10.6μ instead of the present 1.06μ (Nd/YAG lasers). The CO_2 laser provides improved smoke and haze penetration. It is not anticiapted that its adoption would introduce major new problems.

3. Low Light Level Television (LLLTV)

The state-of-the-art in low light level television is exemplified by solid-state video cameras using CCD sensors. Commercial units with 128 x 128 element arrays are readily available. Because it provides a sensor which has fewer parts and consumes less power (no high voltage in camera head) than an LLLTV camera of the 1960-1970 time period, it is potentially more reliabile, easier to maintain, and lower in cost.

Military systems for specialized application such as air-to-air tracking and laser spot tracking can be easily implemented. Furthermore, active laser illumination may be readily added.

4. EO Countermeasures

In a very general sense, EO countermeasures could be considered to encompass all devices and systems which generate electromagnetic waves in the 0.1μ to 100μ wavelength range for the purpose of deceiving or destroying a threat capability. However, it is estimated that at the present rate of progress, the operational wavelengths will be limited to the 0.3μ to 14μ range during the 1980's. Within this range, there are several operational experimental, and projected systems with varying degrees of sophistication.

Current weapons under development by DOD (and, hence, probably under development by the Soviet Union) are likely to render present EO countermeasures equipment ineffective. This makes it imperative that new technology be available for the post-1980 time frame.

The following discussion outlines some of the system readiness problems of the current and projected systems and the associated technical risk areas.

Past and present threats have caused emphasis to be placed on countering the IR homing missiles. At present, the most universal device is the IR flare and its dispenser. Numerous types of flares and dispensers have been developed and are in wide service use, but the introduction of multicolor detectors in the threat weapons will minimize the usefullness of flares in the 1980's. Although most of the reliability and maintainability (R&M) problems associated with the flares have been solved, there is no similar Infrared Countermeasures (IRCM) technology to which these solutions can be transferred.

The other present IRCM technolgoy which has recently been introduced to the Fleet is the AN/ALQ-123. The AN/ALQ-123 is an IRCM system that destroys the accuracy of IR seeking missiles. Its modular nature and BIT features should provide excellent maintainability. However, the IR source used by the system is highly stressed and this may adversely affect the reliability. Initial testing indicates that the system has a mean time between failure (MTBF) which is an order of magnitude lower than that predicted. The AN/ALQ-123 will have limited capability against post-1980 threats and will require major modification to meet the need. The IR source will continue to be a problem in any system relying on an incoherent source to produce the radiation levels required.

The R&M problems associated with the electronics package of systems similar to the AN/ALQ-123 are not unique and can be handled by standard engineering practices. The next projected step beyond the AN/ALQ-123 is to place several small incoherent sources internal to an aircraft (not podded) with reduced stress on each source and greatly simplified electronics packages. This reduced stress on the source should increase reliability and the reduced package size will allow redundancy and increased maintainability.

The next generation of EO countermeasures beyond those employing single or multiple incoherent sources will not only have to address the IR missile problem, but also the increasing use of optical augmentation in radar systems. The major components in an EO countermeasures system of the late 1980's are likely to include an EO warning receiver, a low to medium power laser, and a precise electro-mechanical system for pointing the laser beam. The R&M projections for the FLIR's apply because of the optical equipment related to any pointing system. The EO countermeasures system will require additional accuracy which will compound alignment problems. The laser shows capability in deceiving or destroying almost any present or projected threat, but this capability will be wasted if accurate pointing systems are not available.

One real area of EO countermeasures that has often been overlooked in the initial stage of the development of existing airframes is IR signature reduction. This can be a very important factor when the J/S (Jam to

Signal) ratio for internal or external IRCM systems are specified. IR signature reduction effectively increases the J/S ratio available to nullify the threat for a given power output from the jammer. Signature reduction techniques are fairly well understood and can materially reduce the stress on IRCM power output devices.

B. RADAR SYSTEMS

As in many other areas, the advent of digital circuitry and large scale integration promises to have a significant effect on aircraft radar systems. This effect will be in two major areas, the actual operational performance of the radar itself and the reliability and maintainability of the radar. Most of the impact, for technology that will be available during the middle 1980 era, appears to be of an evolutionary nature.

1. Principal Performance Improvements

a. Solid State Transmitters

Solid state devices applicable to transmitters are currently in development in the laboratory and should be available during the 1980-1990 time frame. Solid state transmitters represent a replacement technology that could be expected to slightly reduce the total system weight and provide significant improvements in reliability. If the transmitter section is composed of several smaller solid state devices in parallel to develop the desired amount of power, the system will have the advantage of graceful degradation since the failure of one element will not completely cause the entire system to fail. The use of multiple devices in parallel lends itself to easy fault isolation and repair through the use of automatic BITE systems.

Solid state radar transmitters are expected to improve the overall reliability and maintainability, and through graceful degradation, substantially improve the readiness of the system. No significant special problems are expected.

After the implementation of solid state transmitters, the possiblity exists that they could be programmed to vary some of their parameters such as power level. This would open the possibility of a digitally controlled transmitter that could vary at least some of its parameters to meet varying requirements encountered during a mission.

b. Solid State Microwave Circuits

Solid state microwave circuits already exist in the Fleet today. The 1980's are expected to see a continuation of the trend to higher power, higher frequency and higher temperature operation. These improvements will permit wider application of such techniques as electronic beam steering, conformal antenna arrays, special modulation techniques and greater isolation between the transmit and receive microwave elements which will provide better, more stable operation in general.

Except for the applications in electronic beam steering, these devices represent replacement technology which will provide improved performance and increased reliability and maintainability. Again, many of these devices lend themselves to control by digital logic and thus to rapid manipulation via a small computer or microprocessor. These devices pose some special risks due to their sensitivity to heat. When used in conformal arrays, they provide graceful degradation but may be susceptible to radiation damage due to their exposed location.

2. Reliability and Maintainability

a. BITE

The major impact to be felt during the 1980-1990 time frame appears to be in the practical utilization of solid state digital technology. One of the prime examples of this is the concept of Built-In Test Equipment

(BITE). BITE can continuously monitor the operation of very complex systems and provide a running commentary on the operation of that system. Upon detecting a failure, BITE can isolate the failure to a relatively small section of the circuitry and tell the repair technician which sections to repair/replace. If BITE is incorporated with a high degree of modularity in the equipment design, the technician can sequentially replace the suspect modules until the BITE indicates proper operation. The failed modules can then be discarded. Such a system can drastically reduce the Mean-Time-To-Repair (MTTR), the use of external test equipment at the O level and the training requirements for technicians.

Recent radar systems have proven microprocessor-based BITE to be the most powerful tool for isolation of a failed component down to a group of modules. Be elevating the importance of BITE to the point where it is a principal criterion for a good radar design, the isolation of a failure can be reduced to a single module.

The low-cost, quickly replaceable module is crucial to an effective BITE philosophy and is the key to an effective maintenance plan.

b. LSI Signal Processing

Advanced radar signal processing will impact a wide variety of functions within the aircraft. A partial list includes flight control, weapon delivery, multiple target detection and identification, radar resolution enhancement and radar signal-to-noise improvement. Practical computations of this magnitude must be accomplished using small, high speed digital computers, which are feasible through the use of Large Scale Integrated (LSI) circuitry. The use of LSI becomes more efficient if the A/D conversion is carried out as early in the signal processing chain as possible, i.e., "close to the antenna". Digital formats are compatible with aircraft data bus concepts and interface problems are reduced to those of interfacing with other sensors, scan converters and with single, head-up cockpit displays.

While LSI is basically used to improve the reliability and maintainability of the aircraft avionics, so much more computational power can easily be made available that the operational performance is almost always improved at the same time. As a result, the expected improvements include both better operational performance and improved R&M. The concentration of computational and control power into one unit, however reliable, is not without its drawbacks. If considerable redundancy is not made available, the failure of one critical element may lead to a catastrophic failure of the entire system.

If some form of graceful degradation can be designed into the system and degraded performance tolerated until the aircraft returns to base, the integrated LSI system promises to be easily repaired through use of a powerful BITE and well partitioned circuitry using rapidly replaceable modules. Such a system should exhibit improved operational performance, improved reliability, reduced MTTR and improved readiness.

C. CONFORMAL ARRAY ANTENNAS

A conformal array antenna is an antenna whose shape is dictated by the contours of the carrying vehicle. As in phased array antennas, it consists of a matrix of transmitter/receiver elements whose relative phase is computer controlled to point the antenna beam. Also, sidelobes and nulls may be selectively computer controlled to limit outside interference or jamming effectiveness. Conformal array technology is based on the desire to:

a. Achieve inertialess scanning,
b. Eliminate large radomes,
c. Obtain large effective antenna apertures, and
d. Make use of digital control technology.

Research is ongoing to develop antennas both for radars and for communication systems. The technology for radar conformal arrays will probably not mature in time for AWAAS applications. Radar antenna(s) for AWAAS applications will be an evolutionary form of current electro-mechanically slewed, electronically scanned planar arrays. The more limited, and more probable, application of conformal array antennas to data link systems is discussed in the following paragraphs.

Because array antennas can produce narrow, jam resistant beams and because of the importance of 4π steradian coverage to data link operation, there is likely to be a need for conformal antenna arrays located on the aircraft skin. The problems of beam directing and of beam forming are being solved in programs such as the Integrated Control and Navigation System (ICNS) for RPV's. The antenna configuration in this case is planar rather than conformal, but (assuming that space on the skin is available) it is reasonable that conformal arrays could be developed to the point of practicality by the early 1980's. In the case of small planar arrays, the protective cover can conform to the local contour of the aircraft.

At least two types of antenna forms are likely to be candidates. One is the so-called Multiple Array Avionics Systems (MAAS) antenna under development by the Pacific Missile Test Center (PMTC), and the other is the ICNS array under development by Harris-ESD of Melbourne, Florida, for the Defense Advanced Research Projects Agency (DARPA) and the Army. Neither type is conformal at present, but might be fabricated in this form. Also, conformal microstrip phased array antennas operating in the D to F bands give some promise, perhaps for missile guidance. Ideally, a very thin antenna which neither disturbs the aerodynamic flow nor protrudes inwardly to disrupt mechanical structures is desired.

Assuming the an antanna of this type could be developed to fit a selected area of the aircraft skin, the principal advantages are:

1. Adaptive resistance to jamming which can be 20-30 dB above that of an omnidirectional antenna,

2. Economy of internal aircraft space,

3. Ruggedness and reliability, and

4. Graceful degradation.

Against these advantages must be balanced some disadvantages:

1. The MAAS form tends to be lossy when many beams are formed.

2. The conformal array antenna needs some added development.

3. The beam-steering and adaptive logic to avoid jammers may be expensive, at least in development.

4. Beam pointing for a narrow beam, while useful in preventing jamming, may be a problem in cases where the location of the transmitter or receiver with respect to the aircraft is unknown.

Due to the exposure of the antenna elements to the aircraft external environment (aerodynamic heating, etc.), conformal arrays may exhibit reliability and maintainability problems not anticipated on the basis of experience with gimbal-mounted planar arrays. It is presently not possible to project the effects of rain and temperature extremes on protective coverings and on the antennas themselves. Also, consideration must be given to the effects of rough handling in the operational environment. O level maintenance for the aircraft skin incorporating conformal antennas will require redefinition.

D. DISPLAY SYSTEMS

1. Alpha-numeric Displays

Many types of displays have been used in aircraft over the years. However, the most common type has been the electromechanical system. These displays have the advantage of high readability in high ambient light environments and are quite satisfactory for use in low light situations with minimal auxiliary lighting. Most of these systems suffer from low reliability, large size, and incompatibility with advancing digital technology.

Light Emitting Diodes (LED's) have distinct advantages of high reliability, small size, and direct compatibility with digital interfaces. The major problems associated with LED's are their tendency to wash out in sunlight and their relatively high power consumption. Much research has already been done to improve the brightness and contrast ratio. As improvement continues, LED's will continue to see an increasing application in avionics systems. For the immediate future, however, LED's will see only limited application in controlled light situations.

Incandescent displays are being used on an increasing basis in avionics systems. They offer reasonable reliability and high readability. The major problem is high current requirement and power dissipation. These displays will continue to be used for simple numeric displays until other technologies are sufficiently developed to replace them.

Gas discharge tubes are becoming increasingly available in the form of dot matrix display systems. These systems are useful for alphanumeric readouts and message displays. Somewhat limited reliability and the need for high voltages limit the use of these systems to special applications.

Liquid crystal displays offer good possibilities for the future. They can be manufactured in any form of dot matrix or segmented display.

Power requirements for liquid crystal displays are in the microwatt region and voltage drive requirements are compatible with monolithic MOS devices. Because liquid crystals function properly over only a restricted temperature range, their use will remain limited unless provision is made for both heating at the low temperature extremes and cooling at the high temperature extremes. New liquid crystals are being developed which will expand the usable temperature range of these displays and improve their switching speeds. Continued development of manufacturing techniques should result in much improved reliability. It will be necessary to investigate the effects of high intensity EMI on these displays and develop shielding techniques where necessary.

2. Video Displays

Presently, the best method to display visual information is the cathode ray tube (CRT). In general, there are two types of tubes, the electrostatic and the magnetic deflection systems.

The electrostatic tubes have small screens and long bodies. Electrostatic deflection is fast but requires large deflection voltages to cover large areas of the screen. In general, focusing is poorer in electrostatic tubes and the image is dimmer. Electrostatic tubes are used in weapon guidance systems such as the Walleye and in instrumentation applications.

Indicator tubes are being developed that have a combination of electrostatic and magnetic deflection circuits. The magnetic deflection is used to move the beam large distances and the electrostatic deflection is used to move the beam small distances very quickly. These are mainly used to write alpha-numerics on the screen.

Present CRT displays are generally bright, efficient, uniform and have a good gray scale range. The cost is low and the reliability can be high (greater than 20,000 hours MTBF). The main disadvantages are bulk, high voltage and nondigital address. In spite of these disadvantages and in spite of continued research on other display types as noted herein, the principal displays in an AWAAS will almost certainly be CRT's. It does not appear that other video display technology will be sufficiently mature for the 1980's.

Research is ongoing to develop flat-panel CRT's, but not all problems have been solved. Most research interest is being concentrated in gas discharge arrays and electroluminescent panels.

These flat display panels are relatively new and have seen only limited use in military environments. Much development remains to be done before flat-panel displays are generally suitable for avionics applications. Limited brightness is a major factor at this time. Also, extensive testing must be done to determine the reliability of these devices in harsh environments. Flat-panel displays should eventually see their greatest usage in CRT replacement applications. However, this application is not likely to be realized in an AWAAS time frame.

3. <u>Digital Scan Converter</u>

Modern aircraft require an integrated display for all electro-optical (EO) and radar sensors. This display should be an X-Y scanning display similar to that of a modern television set. The system must utilize a digital scan converter to convert the sensor formats to that required for the television display.

This system is capable of displaying electronic cursors, target identification symbology, and alpha-numeric symbols. In addition, if the TV display is a color monitor, the colors can be used to great advantage in the display of targets, impact points, potentially dangerous terrain, or the altitude of radar targets in terrain following operations.

It has long been realized that digital scan converters can solve many of the problems associated with analog scan converters. The analog scan converter has had limited use in the military field because of instabilities of adjustments and the lack of an adequate dynamic range.

The digital scan converter requires no adjustments and the life cycle costs are comparable to those of the previously used analog scan converters. The cost of the digital scan converter is directly dependent upon the memory size and the amount of BITE that is incorporated into it. Commercial television images have a display capability that is equivalent to a 256 x 512 x 5-bit digital memory. This memory size is adequate for most TV or IR displays, but it might not be sufficient for high resolution alphanumeric displays or radar PPI images.

Applications of digital scan conversion include:

a. Signal processing to achieve averaged or compressed data,

b. Pixel, line, or frame averaging for nonrecurring noise reduction,

c. Moving target detection,

d. Color coding, and

e. Transformation from rho-theta to X-Y format.

Also, the display system decay rate can be completely controlled by the digital processor.

If a sufficiently large memory is used (at least an extra 4 to 5 bits per word), a sufficiently high-speed computer and added external hardware, BITE may be added to the scan conversion process. BITE systems can give excellent diagnosis of failures and point to fault location.

Other schemes of error correction involve the substitution of adjacent pixel information in locations where dead pixel logic elements are known to exist.

Digital scan converters are sufficiently well developed at present to virtually assure their potential use in an AWAAS. This will result in a major improvement in system readiness over present attack systems, which use analog scan conversion technology.

E. INTERIOR DATA TRANSMISSION SYSTEMS

In past avionics systems, much of the data flow has been on a bit or signal per wire basis. This approach is acceptable for small and relatively simple systems. As systems have increased in complexity so has the amount of data to be transferred. The resulting increase in the number of wires has meant unacceptably high weight and volume requirements and failure rates. These failures result from both accidental and battle damage.

The most acceptable technique to overcome these problems is the use of multiplexed systems. The term "multiplex" is extremely broad, however, and for the purposes of this discussion will be broken into wideband/narrowband and analog/digital.

1. Wideband Analog Multiplexing

Wideband analog signals such as RF, IF and wideband video do not lend themsleves readily to multiplexing techniques. Time division multiplexing (TDM) is not practical and frequency division multiplexing (FDM) would require bandwidths necessitating millimeter wave or optical frequencies. Because the number of signals of this type is relatively small and cabling lengths are kept as short as possible, this class of signals is not recommended for multiplexing. Additionally, the state of the art of the devices required to implement a multiplexed system of this type is not sufficiently advanced. Further development of optical systems such as OIC's (Optical Integrated Circuits), frequency sources, detectors, etc.

could result in application of wideband multiplexing to specific systems. It is unlikely that wideband multiplexed systems will be generally available in a sufficiently mature form during the 1980-1990 time frame.

2. Narrowband Analog Multiplexing

Narrowband analog signals lend themselves to many forms of multiplexing. Low frequency applications (below 400 Hz) lend themselves quite well to analog-to-digital conversion and multiplexing by digital techniques with digital-to-analog conversion at the receiving end. Other analog signals lend themselves to a wide variety of techniques involving both FDM and TDM. Today's monolithic and hybrid technology has developed extremely reliable circuits making analog multiplexing a viable alternative to hardwire systems. Due to the relative complexity of these systems, however, care must be taken to justify multiplexing. The number of signals and the length of the cable runs must be considered.

The wide range of analog multiplexing techniques also creates a maintainability problem. It would be extremely difficult to train maintenance personnel, especially 0 level personnel, to troubleshoot all the various multiplexing techniques. The answer to this problem is two-fold. The first and most recognized solution is the inclusion of extensive BIT and fault isolation to the SRA in each design. A second area to be addressed is standardization. This would result in a decrease in the proliferation of types of multiplexing systems, making training of maintenance personnel much simpler. Also, increased development of specialized microcircuits should result in higher reliability components for multiplexed systems. This has been the result in standardized digital systems.

Narrowband analog multiplexing technology can easily be drawn upon in AWAAS development, and, given adequate standardization and hardware configuration control, its use should not adversely affect system readiness.

3. Narrowband Digital Multiplexing

Low to medium data rate digital multiplexing systems offer perhaps the greatest applicability to an AWAAS avionics system. Much work has already been done in the way of standardization of hardware and techniques such as AR-63, AR-64, and MIL-STD-1553A. The result of this standardization is that highly reliable microcircuits are becoming available which will make digital multiplexing simple to implement in most applications. This ease of implementation should also lead to increased use of redundant data buses resulting in extremely reliable systems. Again, maintainability may be a problem unless extensive use is made of BIT and fault isolation during system design.

Further definition of basic functional circuit blocks should lead to improved microcircuits and a building block systems approach. Further development of transmission lines, coupling mechanisms, drivers, and receivers will result in improved system reliability.

This technology area is well within reach for AWAAS development and should be highly reliable by the early 1980's.

4. Wideband Digital Multiplexing

High data rate digital multiplexing systems are the subject of much current development work. Particular attention is being paid to fiber optic transmission media, transducers, and modulation formats. A more detailed examination of fiber optics data transmission is provided below. Although it may not be practical by the early 1980's, an attempt to realize better system definition and some form of standardization should be made in the next five years. In the absence of standardization, the system designer must choose the best multiplexing techniques for a particular application. Again, BIT and fault isolation must be prime considerations during design.

An alternative to high data rate digital multiplexing is the preprocessing of signals for data compaction. New microprocessors make this technique an attractive alternative to wide bandwidth systems. The results of this data compaction can then be handled through standard multiplex channels such as defined by MIL-STD-1553A. This approach is judged to be both practical and reliable for application during the 1980's.

5. Fiber Optics Data Transmission

The recently completed A-7 ALOFT (Airborne Light Optical Fiber Technology) flight demonstrations have established the feasibility of utilizing fiber optics technology for airborne data transmission applications. The fiber optic components utilized in the ALOFT system are, however, not generally suitable for use in operational avionics equipment. Fiber optics technology is still in the research and development stage. Numerous performance, reliability, and maintainability problems must be addressed and solved before operational fiber optic systems are feasible. The ongoing NAVAIR sponsored Fiber Optics Technology Program has as its primary objective the development of fully MIL-qualified, highly reliable, standard, multi-sourced fiber optic components for airborne system applications. It is estimated that at the present rate of progress, this program objective will not be totally achieved until well into the 1980's. The subsequent discussion enumerates the advantages to be gained by utilizing fiber optics and briefly discusses the major problem areas.

The foremost performance advantage offered by fiber optics is its total immunity to electromagnetic interference (EMI). Since the transmission path is a totally dielectric medium (glass), the communication link is not affected by EMI sources and, in addition, does not generate any EMI. This total electrical isolation also eliminates ground coupling problems, cross-talk, short circuit loading, spark/fire hazards, and provides a very high level of immunity to EMP. The second major advantage offered by fiber optics is the capacity for very high data rate transmission. Data rates far higher than those normally feasible with coaxial cable can be implemented in a relatively simple manner with fiber optics. Other advantages include reduced size and weight, compared to an electrical system of equivalent data transfer capability, and the ability to withstand relatively high temperatures.

The major airborne applications for fiber optics include point-to-point digital data transmission, data bus systems, and specialized analog data transmission paths.

It is anticipated that high data rate transmission requirements will be implemented via a dedicated point-to-point system. An example would be the transmission of serial digitized radar video which could require a data rate as high as 200 Mb/S.

It has been proposed that aircraft sensor, control, audio, and warning signals be transmitted over a central, fiber optic data bus. The high data rate capability of fiber optics makes it feasible to implement a "digitally transparent" data bus which would simplify the bus interface and control functions. The question of the applicability of MIL-STD-1553A to fiber optics must also be resolved.

The use of fiber optics transmission links to control weapons would totally eliminate the possibility of the accidental release or arming of a weapon due to electromagnetic interference, which has been a very serious problem.

There are three basic problem areas associated with fiber optic technology which should be considered before a planned system is committed to the extensive use of fiber optics. First, as stated previously, fiber optics is still in the research and development stage and consequently, there are a number of fundamental technical problems which have not yet been solved. All presently available source diodes degrade with time. The LED power output is observed to continually decrease during forward bias operation. Half-power lifetimes from a few hours to 30,000 hours have been reported for various device types. The physical mechanism causing this degradation has not yet been identified. This reliability problem will not be solved until the physical degradation mechanism is identified and the necessary changes in semiconductor material, device structure, and processing methods are made to totally eliminate the basic cause of the degradation.

A second problem concerns the mechanical degradation of the glass fiber with age. This problem is especially severe when the fiber is exposed to moisture and other contaminants, and is accelerated by the mechanical abrasion of the fibers against each other. In the case of a low-loss single fiber, an in-line process which applies a protective plastic coating to the fiber is used to control this problem. This solution is not immediately applicable to the bundle technology for a number of reasons including cost. The present solution is to apply a lubricant to the fibers and hope that it will limit the effects of abrasion to an acceptable level. It is very doubtful if a loosely jacketed fiber bundle of this type will survive the severe aircraft environment over the long term.

A third basic problem concerns the fact that the glass fibers are extremely soft to nuclear radiation. It is possible to select certain glass fiber types which are more immune to radiation and might offer acceptable performance. Unfortunately, the best radiation hardness is achieved at a wavelength of 1.06μ. Formidable technical problems are then encountered in trying to develop the necessary source and detector diodes for this wavelength.

All of these technical problems are currently the object of major research and development efforts, especially as they impact single fiber technology. It is questionable if additional government sponsored research would hasten the solution of these problems, except possibly in the case of the 1.06μ components development. The present motivation for solving these problems is the promise of a huge and lucrative, future telecommunication market.

The second area of uncertainty involves the development of the necessary fiber optics hardware such as connectors, sources, detectors, ruggedized cables, transmitter and receiver circuits, and optical couplers. This effort is somewhat affected by basic technical problems. However, it is still primarily an engineering development task. Progress in this area has been slow for a number of reasons. First, coordination and direction from the overall system standpoint is required. Each individual component design should be optimized to meet overall system requirements. To date, much of the component development has suffered from a lack of overall system definition. Component development has also been hindered by a premature effort to standardize and prevent proliferation of designs. It is very difficult to standardize hardware before the basic system requirements have been totally defined and before suitable hardware is developed. It would appear to be of more benefit to allow the exploratory development of various fiber optic component concepts and designs and then to standardize on the basis of demonstrated performance characteristics. In any event, promising component development programs have been hindered by the fact that they may not have conformed to some prematurely defined standard.

The final factor is that, since fiber optics has never been employed in an operational system, reliability and maintainability procedures and programs do not exist. Reliability and maintainability considerations should be made part of the basic component and system development specifications. The practical installation experience gained in the ALOFT program can be utilized here. Conservative design and extensive component and system reliability testing will eliminate much of the potential risk before the first fiber optic system is installed aboard an aircraft. Maintainability will depend on the details of the system design. Careful design and installation of the fiber optic cables is required to guarantee acceptable lifetime. Adequate mechanical and environmental protection must be designed into the cable. Emergency end finishing and splicing techniques which are suitable for field use must be developed. All critical components should be easily serviceable in the field. Specialized fiber optic test equipment will have to be developed. For example, the fiber optic equivalent of an ohm-meter is required to check for fiber continuity. Provisions for built-in testing could be invaluable. In addition, programs will be required to properly train maintenance personnel. Since optical-to-optical interfaces are involved, extreme attention to detail will be required to guarantee day-to-day cleanliness of these interfaces. A primary requirement of the basic hardware design is to protect the optical interfaces. However, these interfaces will still be susceptible to contamination by moisture, dirt, aircraft fluids, etc. Periodic inspection and cleaning of the optical interfaces will be required as part of the maintenance procedure. The accumulation of moisture at an interface could, upon freezing at altitude, render the fiber optic system inoperative. It is doubtful if solutions to all of these problems will evolve naturally. It will probably be necessary for the first large scale application programs to assume much of the cost and responsibility for the successful operational deployment of fiber optic systems.

A final element of risk involves the basic technology approach which is being taken. The bundle technology has been selected by the military for the airborne application and is being pursued exclusively. There are basic research and development problems which must be solved for both the bundle and single fiber technology. The great majority of basic research is, however, directed toward the development of single fiber systems by commerical communication vendors. The results of some of this research will be applicable to bundle technology. In general, it appears that single fiber technology will achieve wide acceptance, will be highly developed technically, and will be low cost. If the problems concerned with bundle technology cannot be solved in a reasonable time, then it may be necessary to re-evaluate the basic technical approach and consider single fiber systems. Such a drastic change in overall program direction would result in a delay in the application of fiber optics to operational systems.

F. DATA LINKS

Aircraft operating in the post-1980 time frame will require two types of data links. One type will be used for communications and for other low data rate applications. The second type will be used in wideband applications requiring transmission at high data rates. Examples of such wideband systems are missile data links which use a video link from weapon to aircraft and a command link back to the weapon, and intelligence systems which require real-time transfer of radar or reconnaissance camera data.

In view of the present moves toward requiring standardization of data links, it is unlikely that the development of an AWAAS would offer sufficient justification for a unique data link. For this reason, a brief overview will be given of some of the more likely "candidate" links. These are data links which are now in development and which offer some significant degree of jam resistance and data security.

The low data rate link of the 1980's will perform functions similar to the functions now performed by the NTDS links. These functions could (at minimum) be performed by existing, secure A/J data links from inventory.

If a low data rate link with greater common usefulness is required, the Joint Tactical Information Distribution System (JTIDS), if it is operative in the time period of interest, would be the logical candidate. It involves a number of new and useful data encoding techniques but is essentially limited to data rates $\leq$ 50,000 bits/sec. If JTIDS is delayed or abandoned, then a new data link concept might be in order.

Some wideband information systems, such as the Walleye and Condor weapon control data links, are carried in pods, as opposed to being internal to the aircraft. These current data links are essentially nonsecure links. As the Electronic Countermeasures (ECM) environment becomes increasingly sophisticated, the current data link systems will operate reliably a smaller percentage of the time because of susceptibility to hostile jamming. To overcome this threat, wideband data links will need to be developed which have Anti-Jam (A/J) protection. A/J protection can be added by increased electronic sophistication and by the use of narrow beam tracking antennas. In severe ECM environments, a combination of both may be required. In any event, it is difficult to provide a high degree of jam resistance in this type of link.

At this time, there is not the same pressure to standardize wideband video links as there is to standardize narrow band tactical or command links. This is probably because practical secure wideband links are in an earlier stage of development.

Wideband data links with a significant amount of jam resistance are currently under development for RPV'S (the ICNS) and for missiles (Air Force-Navy Joint Service Weapon Data Link--JSWDL). Both types of wideband data links will use both the technique of data rate reduction and of signal bandspreading to achieve resistance to jamming. The development of data rate reduction processors and of bandspread modems is likely to have progressed to the hardware availability stage by 1980-1985. Thus, wideband data requirements for an AWAAS might be fulfilled by one of these links. The data rate capability of the modems will be of the order of several megabits/sec. The data will be digitally encoded for interface with either automatic data interpreters or displays (pictures and alphanumerics) interpretable by human operators.

If a completely new data link must be designed, there are two important aspects to consider. The first of these is to minimize (by any one of several techniques) the rate of data transmission. This means that some type of data memory at both the sending and receiving terminals will be needed to "match" the asynchronous data to the needs of the user, whether human or automated. The most efficient data transfer (in terms of jam resistance in a fixed RF bandwidth) is to deliver data at the slowest rate possible (in the limit, at a minimum constant rate) which meets the user's needs. Since the rate of arrival of input data is not necessarily constant but may be in bursts with intervals of "dead time" in between, there should be a buffer memory at the sending end. There may also be procesors which mathematically transform the input signal to minimize transmission of redundant data. At the receiving end, the regular input data stream must be stored and presented to the user as needed, which might be at irregular intervals. Thus, a buffer or holding memory is needed at the user terminal. Decoders and/or equipment to perform the inverse of any mathematical transformation performed at the transmitter will also be required.

The second important factor is that if the greatest possible resistance to jamming is to be obtained, the signal waveform should be designed to allow a signal processor to correctly interpret the signal when it is submerged in noise (S/N ratio <1). A general measure of the ability to recover a signal from a noisy environment is the "processing gain" provided by the modulation/demodulation method or "modem." The maximum processing gain available in decibels is defined as

$$10 \, \mathrm{Log}_{10} \frac{\text{BW modulated}}{\text{BW data}} = \text{Processing Gain},$$

where, BW modulated = Bandwidth of signal after modulation for band spreading, and

BW data = Bandwidth of data before modulation (base bandwidth).

It is evident that there are three ways of increasing the processing gain:

a. Decrease the base bandwidth of the data.

b. Increase the modulated signal bandwidth by a technique for spreading of the RF spectrum of the modulated signal. This is useful until all the available RF channel bandwidth has been occupied by the modulated signal.

c. Obtain a channel assignment with larger RF bandwidth and continue the process outlined under (b). This reaches one of three limits:

(1) The cost limit (broad band equipment is costly),

(2) The technology limit (only limited bandwidths are technically feasible), and

(3) The legal limit (operation over a wider channel is denied by some frequency assigning authority).

The proven techniques to be used under item (b) are generally one of three:

a. Direct Sequence Pseudo Noise (DSPN). In this case, useful for spreading up to 50 to 100 MHz, the modulator multiplies the incoming data stream by a pseudo random digital sequence. The relatively narrow band data stream may have its bandwidth increased by a few tens to a few thousand times. At the receiver, the incoming data is multiplied by a digital sequence synchronous with that of the incoming signal and the original data may be recovered even though the S/N in the wide band channel is less than unity.

b. Frequency hopping in a fast random sequence. This technique has many variants but, in general, the transmitter frequency is rapidly shifted over some band, dwelling at any one frequency for only a very short period of time. At the receiver the local oscillator is shifted synchronously with the incoming signal to give a constant (low) IF which contains the original data. This technique can be effective over bandwidths of several hundreds of megahertz.

c. Chop-chirp. In this technique the transmitter is swept rapidly over a range of frequencies while simultaneously modulating the swept RF with a coding sequence. At the receiver, the swept RF is passed through a dispersive filter with matching inverse slope thus creating a high intensity impulse at the end of the sweep. The dispersive filter can be mechanized with the aid of surface acoustic wave (SAW) devices. They possess the quality of being rugged and reliable but are somewhat difficult to make and use.

At present, the ICNS system and some of the other systems under consideration are testing all three techniques. The experience gained in these systems will be available for application to an AWAAS data link.

The transmitter memory, transmitter, receiver, receiver memory and display are all amenable to BIT because of the digital nature of the data. Test sequences can be periodically interleaved with the data and transmited. The results of these transmissions can be monitored at the receiver for correct reception. If link performance is not as expected, diagnostic sequences could be initiated via the command uplink to localize the malfunction.

G. COMPUTERS AND MICROPROCESSORS

Increasingly sophisticated avionics systems have created a demand for faster, more complex data processing devices. As the technology advanced, this demand was satisfied by developing faster and more complex computers and microprocessors and incorporating them into aircraft systems. Both computer and microprocessor technologies have grown rapidly and have led to the use of a large variety of processors.

The foremost problem introduced by the large number of processors involves software standardization. The cost of creating a software development package for each new processor is high in relation to the cost of the associated hardware. Instruction sets and languages have increased at nearly the same rate as processors. A standard family of microprocessors and computers could be defined such that they share a common upwardly compatible instruction set and architecture. The Texas Instruments (TI) 990/9900 series processors are an example of such a family. Military grade I^2L and MOS microprocessors and TTL minicomputers are provided with upward compatible software. The Navy has two computers, the AN/UYK-20 and the AN/AYK-14, which constitute a beginning of a family. Both the TI and the Navy families were developed to reduce software costs and to increase software Reliability and Supportability (R&S).

Additional problems involving software are related to testing and documentation. Extensive software testing must be performed to prevent failures due to unexpected combinations of input events. Program documentation is a costly, but unavoidable, necessity. Future modification and maintenance require that proper reference material be available. Software R&S are discussed in a subsequent section.

The proliferation of data processors has also led to hardware problems. Each computer or microprocessor has a unique interface with its surroundings. A standard should be adopted which would allow all microprocessors and computers to communicate with each other and with various aircraft peripheral equipment, including maintenance systems. The bus must be designed such that faults in any of the processors or systems will not cause other bus failures. MIL-STD-1553A provides for such a standard bus system. It is currently being implemented with the AN/AYK-14 computer. An evolution of MIL-STD-1553A technology is the most realistic candidate for AWAAS.

Computers have introduced special maintenance problems of their own. In order to isolate faults a technician must be familiar with the software as well as the hardware. Special test equipment is also needed to step through programs and analyze data on the various parallel data paths. To reduce the need for a great number of highly skilled maintenance technicians, extensive built-in test equipment must be designed into the system. Redundant processors might be required if BIT execution requires processor operation because, if the processor fails, BIT fails, and faults could not be isolated to a satisfactory module level.

Future processors will be required to be faster, have higher component density, and consume less power than those of today. I^2L circuits are very dense (less than one-tenth the area per gate of TTL) and consume less power than low power Schottky circuits. Manufacturers are predicting that by the 1980's complete microcomputers will be contained on a single I^2L substrate. These computers would contain as much as 64K words of memory. I^2L microprocessor speed will be approximately 600 KOPS, twice that of microprocessors today. I^2L noise margins, however, are low. This is overcome today by restricting all I^2L signals to a chip and interfacing from the chip with TTL drivers. The relative power dissipation of these drivers is higher than the entire microprocessor circuitry. Including more circuitry on a substrate (i.e., processor and memory) will reduce the number of drivers required and the total system power dissipation.

With the reduction of microcomputer size, it would become more feasible to incorporate redundancy. Several microprocessors might operate in a distributed network. Each processor would operate at somewhat less than 50% of its maximum speed capability. If a fault were to be detected in one of the processors in the net, others would take over the tasks of the defective one, thereby, improving the overall system reliability.

In systems requiring extremely high processing rates, ECL microprocessors may be used. Currently, only slice type microprogrammable processors are avilable. It is doubtful that complete microcomputers will be available in ECL because of its high power dissipation properties. This circuit will only be used as an ultra fast processor when power requirements are justified.

H. SOFTWARE

1. Reliability

Reliability of software can be achieved by aggressive quality control during the software life cycle. The quality assurance procedures are used to systematically assure that the quality of the software will meet the needs of the users, will be in accordance with applicable standards and specifications, and will be designed to minimize the probability of system failure during operational use.

Factors which influence the reliability of the software include:

a. Specifications, standards, system requirements and the contract.

b. Software documentation.

c. Software standards and conventions, which include the developer's "in-house" procedures for developing software.

d. Software self-test and defensive programming, including input/output parameter reasonableness checks, smoothing, sum checking, overflow compensations, failure diagnostics, etc.

e. The software design, including its logic design, modularity, and the amount of interdependence between the program units.

f. The programming language.

g. The operating stability of the software, which is its ability to handle power interrupts and to perform orderly shutdown without the loss of resident data or program control.

h. The provisions in the software for monitoring the status of the weapon system equipment and the computer on which it is running.

i. The provisions in the software for degraded modes of operation due to failure of the weapon system equipment and/or the computer on which it is running.

The techniques for ensuring effective quality control and reliable software are:

a. Design review throughout the development phase to assure completeness and accuracy of the requirements and documentation materials, which include such items as specifications, documentation, flowcharts and software.

b. Audits throughout the software life cycle to assess the conformance of the software system with technical and management requirements and standards.

c. Test and Evaluation (T&E) throughout the entire software life cycle.

d. Configuration management procedures, including the establishment of a software change review board at the end of the software development phase.

e. Data management procedures.

f. Close liaison among all activities responsible for avionic system hardware and software that interfaces with the weapon system software where modification of the avionic system hardware/software would impact the weapon system performance.

2. Supportability

Good software supportability results from these factors:

a. Minimization of the complexity and interdependence of program units through a well developed design,

b. Preservation of the integrity of that design through the coding and implementation stages, and

c. Acquisition of control of all hardware and software required to operate, simulate, and support the computer programs. This includes the complete set of documentation required for the operation, maintenance and modification of these programs.

Items to be considered in assuring good supportability of the weapon system software should include:

a. Development of control logic for the software, which will allow software support personnel to easily understand and follow the software program control structure and which is readily identifiable in the delivered documentation.

b. Development of a complete set of software documentation, including a well annotated source listing for not only the weapon system software but also support software, Automatic Test Equipment (ATE), software and trainer software.

c. Traceability of the software with its documentation,

d. Acquisition of weapon system hardware, general purpose computer equipment and peripherals and all other facilities for software support,

e. Designation, early in the software life cycle, of the activity tasked with the responsibility of software support,

f. Training of the personnel responsible for supporting the software,

g. Acquisition of all support software necessary to modify, test, stimulate and simulate the weapon system software,

h. Preparation of a Software Life Cycle Management Plan according to NAVAIR INST 5230.5, and

i. Development of data management and configuration management procedures.

Frequently, the supportability of the weapon system software is diminished by failure to acquire all the support software including such items as compilers, assemblers, editors, boot strap loader, algorithm simulations, and software for simulators. Supportability of the software is also reduced when the support software which has been acquired is not transportable between the developer's facilities and the software support activitiy's facilities.

Another pitfall in achieving good supportability has been to designate the activity tasked with the responsibility of software support too close to the Navy Support Date. Because of this the Software Support Activity (SSA) may not have adequate hardware (both weapon system and automatic data processing) with which to support the software and may thus be required to take over the support of the software only months or weeks after their personnel have received training about the software they are to support. If the SSA is designated early in the software life cycle, they can assist in contractor monitoring, can witness software testing, and can prepare for a smooth transition of the software support responsibility from the developer to the SSA.

Software documentation is a key element in assuring software supportability. In spite of this well-known fact, the requirement for software documentation frequently is removed when project funding becomes tight. Producing software documentation after the software is written is a more costly approach and tends to reduce the transfer of knowledge because the original programmers are normally no longer associated with the project. As a result, the software documentation is produced by either a person who did not write the program or, on occasion, is produced by the SSA personnel.

Software documentation procedure requirements are well defined, currently by SECNAVINST 3560.1, and previously by WS-8506. These requirements are fairly well known and well understood throughout government and industry. Further, software management procedures now being developed by committees such as the Naval Air Systems Command Software Management Advisory Committee (NASMAC) and by the Tactical Automated Data Systems Office (TADSO) provide a practical set of standards for software management. Some of these documents are:

a. NAVAIRINST 5230.5, Responsibilities and Requirements for Preparation of Software Life Cycle Management Plans (SLCMP)

b. Naval Air Systems Command Software Management Manual

c. MIL-STD-1697 (Draft), Military Standard Tactical Software Development

It is expected that software management procedures now being developed by NASMAC, TADSO, and others will be well known and understood throughout government and industry in the early 1980's. Therefore, practices are now in existence or in development to deal with the problems of software development, management, control, documentation, and supportability. As noted earlier, difficulties most often occur in failing to ensure that the funding and management attention are directed toward the execution of these policies and procedures. If software design, testing and documentation are assigned low priorities through management decisions or by default, the results will probably have a much greater adverse effect on software supportability, and hence, on system readiness, than is inherent in the software development and support effort itself. Thus, the total history of management decision making throughout the development of software for AWAAS will perhaps have greater impact on software supportability and system readiness than technological uncertainties.

I. MICROELECTRONICS

As recently as 1970, large scale integration (LSI) integrated circuit silicon devices were defined as those having greater than one hundred transitors. Today, large LSI chips may easily contain in excess of twenty thousand devices, manufactured at a cost many times less than that of their cruder counterparts produced in 1970. The packaging technologies which provide electrical interface and mechanical and environmental protection for the silicon devices have matured at a much slower pace because of reliability and cost considerations. This section presents advanced electronic technological considerations that pertain to:

a. LSI technologies,

b. Microcircuit packaging technologies, and

c. Potential problems related to their uncontrolled utilization.

1. LSI Technology Considerations

The LSI technologies available for this project time frame will be those of Integrated Injection Logic (I^2L), Metal Oxide Semiconductor/ Silicon on Sapphire (MOS/SOS), and Charge Coupled Devices (CCD).

I^2L-LSI technology will be used for complex functions that the semiconductor industry will develop for large volume commercial applications. The procurement of I^2L devices to military specifications will be acceptable to the industry at a significantly higher price than commercial components, due to additional screening and testing requirements. The principal problem in acquiring I^2L devices will be the confidence level of the functional testing specified. As with present military procurement problems concerning microprocessors and their peripheral devices, the much greater density of I^2L devices may outstrip the avilability of total test capability. Necessary test capability will not be available for either the user or supplier to absolutely ensure that the procured hardware is as specified. Computer simulation techniques will have the ability to verify logic designs as intended, but total testing capability and test confidence will lag. I^2L devices will find uses in military applications where programmability, high speed, high current drive, and hybrid combinations of analog-digital functions are requirements.

MOS/SOS-LSI technology will most likely be used for a majority of custom military digital processing applications. This class of electronic devices will be available in two principal subgroups, silicon gate N-channel MOS/SOS (Si-NMOS/SOS) and silicon gate complementary MOS/SOS (Si-CMOS/SOS). The SOS technologies afford several direct benefits to military application:

a. Radiation hardness,

b. Fast device operation,

c. High noise immunity,

d. Low power digital and very low power analog applications, and

e. Static operations where nonvolatile memory storage is required.

The more available of the two technologies will be Si-NMOS devices that will be primarily military extrapolations of present-day NMOS microprocessors and their associated support peripheral chip designs. The principal benefit of Si-NMOS/SOS will be the carry-over familiarity of system designers from present development work. The disadvantage will be the lack of widespread availability from the semiconductor industry. Si-CMOS/SOS will be more widely employed in dedicated or custom LSI applications. This Si-CMOS/SOS dedicated LSI approach will offer the greatest improvement to military applications because of:

a. Highest reliability of all LSI technologies,

b. Most complete BIT/BITE capability,

c. Lowest system life cycle cost,

d. Fastest non-bipolar processing capability,

e. Most compatible technology with available devices, and

f. Highest developed Design Automation (DA) support.

The disadvantages of the primarily custom design Si-CMOS/SOS technology are expected to be the following:

a. Firm system design, resulting in limited future changeability,

b. Highly visible front end costs (Note: These costs do not continue into the production phase as is often the case with microprocessor software based designs.), and

c. Sources limited to contractors with in-house wafer process capabilities that are primarily linked with military program support.

The CCD-LSI technology will be utilized in the areas of high density digital memories, Opto-Electronic (OE) sensors, planar arrays, and specialized hybrid analog-digital functions. Many potential applications of this technology are presently being investigated, but significant work remains to be accomplished in order to project its characteristics of high density and charge packing for use in the above-mentioned applications. The memory, sensor, and display applications should be available for use by 1982, but the extensive and exotic applications that are currently being predicted may not be available in the 1980-1990 time frame.

2. Hybrid Technology Considerations

Hybrid microelectronic packaging technologies, thick films and thin films have been attractive to electronic system designers because of the significant advantages of size, weight, component density, and performance. Hybrid microcircuits have also offered distinct advantages over conventional packaging approaches in applications requiring extreme combinations of electrical performance and mechanical, thermal, and environmental stresses. Navy avionics designers will continue to resort to the use of these higher density electronic packaging technologies as the trend of increased performance requirements packaged in a finite volume continues to escalate. This increased density will be brought about through the increased use of medium and large scale integrated circuits, packaged individually or in combinations in hybrid packages, to solve complex functions or to process increased amounts of data.

Because of the sophisticated and complex nature of the hybrid technology brought about by the close proximity of components, materials, substrate and package, reliability and cost improvements can only be achieved through proper process and material controls. The miniaturization of circuit elements tends to compound fabrication and test problems, making proper control increasingly difficult. Small quantity procurements, typical of military acquisition practices, currently prevent stabilization of many of the processes demanded by a mature technology attempting to improve upon its reliability and cost factors. Many of these problems will be alleviated in the next five years with improvements currently being developed and employed by the high volume semiconductor industry.

The hybrid technology of the early 1980's will be considerably different in the realms of influence of the military market on the semiconductor industry, material stability, testability, and possibly package configuration. The largest impetus will be applied by the semiconductor industry. Unless the hybrid microcircuit is composed of passive elements, its primary role is to provide electrical intercomponent connections and mechanical and environmental protection for semiconductor devices. At the present time, the semiconductor industry is driving toward increased circuit complexity. That is, more functions or computing capability are required on each chip. This density will severely impact the intra-hybrid testability scenario and the confidence test levels which will be achieved. Current predictions of 1982 complexities of hundreds of thousands of transistors per chip demonstrate the fact that BIT and BITE must be built into hybrids and, if introduced on the semiconductor, will occur at almost no increase in hardware cost. In the long run, this will actually reduce life cycle costs.

The semiconductor technology will also shift its bonding procedures in the next several years such that almost all routine chip-to-hybrid substrate attachment will be performed by automated machines. This will increase interconnection reliability since the human element will be eliminated and, at the same time, should reduce bonding costs. In addition, this new chip bonding mechanism will permit increased device test and burn-in screening prior to bond attachment, a significant positive reliability factor.

Another area of hybrid technological improvement will occur in the realm of materials and their associated stabilities, reliabilities, and costs. Thin film material systems will permit mass production of multilayer, multiple sheet resistivity devices. Thick film resistors will have improved temperature coefficient of resistances (TCR) and will be much more process predictable. Should commercial industries such as the automotive and home appliances groups provide enough development capital, the non-noble thick film ink systems will mature and become a viable alternative to the precious metal constituents now in military use. Conductive and non-conductive epoxies will also mature and become much improved.

Hybrid packaging will also change significantly in the next six to eight years. Increased material and tooling costs have driven the price of large hybrid packages to an unacceptable point for throwaway modules, and must be reduced. Increased circuit densities, sophistication, and demand for testability require that larger packages with more dense connection schemes be devised. Emphasis will be placed on ceramic packages and packages that are not totally hermetically sealed but instead, isolate small hermetic areas, or use devices that eliminate the need for hermeticity altogether.

3. General Microcircuit Problem Areas

During the course of a recent NAC microelectronic technology investigation, a potentially serious condition with respect to present-day and future microcircuit usage became increasingly apparent. This problem is the extremely high probability that many of the microcircuits with which many of our primary electronic systems are constructed have become, or soon will become, unavailable for purchase. This will produce a critical shortage of components for the support of the manufacture of additional production systems, repair parts and/or assemblies, and for the support of any mobilization needs.

Most microcircuits used by the military now and contemplated for near-term future use fall into the following four categories:

a. Commericial, off-the-shelf microcircuits in the small scale integration (SSI), medium scale integration (MSI), and large scale integration (LSI) technologies, spanning the range from digital data networks to complex microprocessors,

b. Universal arrays,

c. Hybrid assemblies, and

d. Custom LSI assemblies.

Although the physical characteristics of these microcircuits tend to fall into these four categories, the problems that are of primary concern stem from characteristics of the technology and the market place and are equally applicable to all four categroies. That is, these problems stem from the facts that the microcircuit industry is driven by commercial, rather than military, market pressures, and that the configuration controls imposed by many of our current contracts are oriented toward the previously utilized discrete element circuit architecture in contrast to today's functionally oriented, high-technology assemblies. These two conditions lead to a potentially fatal circumstance which results from the commercial microcircuit supplier having abandoned a given integrated circuit technology product line due to increased pressures from his competition. This is typically the result of the competition having introduced products utilizing further improved technologies and offering higher packaging densities resulting in smaller size, higher yield, lower cost, improved operating speeds, lower power dissipation, etc. When a microcircuit supplier drops any given production technology, he loses the ability to continue manufacture of military microcircuits utilizing that manufacturing technology on a broadly based, closely monitored, high volume basis (i.e., the production concept which tends to yield extremely uniform, highly reliable semiconductor products, and upon which the military part qualifications were based). Since the military production typically constitutes an insignificant percentage of the supplier's production from any given technology, the military influence on a decision to maintain an expensive manufacturing capability is usually minimal.

As a result of this situation, the Navy is being told more and more frequently by the contractors that they are unable to supply the required repair parts, modules and assemblies because they are now unable to buy one or more of the microcircuit parts required. In many cases, there are no direct substitutes, the space and power constraints eliminate the possibility of utilizing a discrete element replacement, and the costs of redesign and/or requalification are prohibitive. In these cases, a number of relatively unattractive options exist. They are:

a. Development, test, and qualification of a replacement microcircuit from the original or an alternate supplier, or

b. Development, test, and qualification of an alternate circuit mechanization which utilizes available microcircuitry, or

c. The replacement of this system with a new system, causing the abandonment of a useful system due to the lack of one or more vital, but unavailable, parts.

In most cases, any solution to this type of problem results in the unavailability of repair parts, new production, and/or requirement mobilization hardware for many months until the problems can be solved. This is accompanied by an unplanned expenditure of funds to pay for analysis, redesign, requalification, and production of replacement hardware and spares, technical manual changes, etc.

To further complicate this situation, our electronic systems are filled with microcircuit products, produced by myriad suppliers with various manufacturing technologies, and our present configuration control processes do not allow us to identify "which" technologies (Rockwell PMOS/metal gate process, RCA/CMOS/silicon gate double-guarded process, etc.) are employed "where" (e.g., A7, A6, LAMPS) to do "what" (e.g., A7 navigation system, A6 central computer, HARM guidance system). As a result, the Navy will typically not be aware of a potentially serious, long procurement delay. Nor will the Navy be aware of the need for significant levels of R&D qualification and production funding until a few weeks or months after the needed parts are ordered, and the supplier becomes aware that he cannot purchase the necessary high technology parts for support of his production.

The following actions must be taken on a priority basis to gain control of this very serious situation:

a. New systems being developed for the Fleet must be procured in such a manner as to yield effective configuration, qualification, and logistic support control and support for the high techology portions of the system.

b. Concepts and methods must be developed to reduce the severe time and cost penalties for qualification of primary advanced technology product elements. Methods must be developed to allow the use of pre-qualified elements in the initial R&D modules so that initial tests for feasibility, followed by ADM and EDM hardware, can utilize the final high technology product and eliminate or reduce the present problems relating to time/cost which preclude the utilization of these promising circuitry elements.

The end effect of these actions should be a computer assisted technology guidance and configuration control capability, giving the Navy the ability to identify which microcircuit technology/manufacturing process/manufacturer combinations are being used in which portions of what Fleet electronic systems in which aircraft, missile, etc. With this information, coupled with a real-time dialogue with the microcircuit manufacturers involved, it will be a straightforward problem to:

a. Identify technologies and/or specific manufacturing processes that are planned for abandonment with sufficient lead time to allow an orderly choice of operation including:

(1) The utilization of an alternate part, or
(2) A lifetime buy of the needed microcircuit, or

(3) The purchase of an X year supply and the initiation of the development of a replacement microcircuit under an alternate technology;

b. Identify applications of this technology (i.e., Module 35A3 in the A7 Navigation System, Module 76A521 in the HARPOON Guidance System, etc.);

c. Notify NAVAIR/ASO/CFA points that specific parts will no longer be available after a certain date and make recommendations regarding viable options.

In this manner, advanced technology microcircuits can be employed in vital Fleet hardware, but their use can be controlled in such a manner as to ensure the ability to support these systems logistically for their anticipated service lives.

J. MICROWAVE INTEGRATED CIRCUITRY AND SURFACE ACOUSTIC WAVE DEVICES

1. Microwave Integrated Circuitry (MIC) Technology

Microwave Integrated Circuitry (MIC) offers a three-to-ten times reduction in size and weight compared to earlier forms of planar and coaxial microwave circuit construction. This technology also offers an estimated three-to-five times improvement in reliability as a direct result of its geometrical planar construction and the minimization of discrete components. This form of construction facilitates maintenance by module replacement. The concept of system integration inherent in custom MIC assemblies allows improved freedom in partitioning a microwave system into functional modules in accordance with electrical isolation requirements and minimizes the number of module types which must be stocked for maintainability.

The MIC form of circuit construction also allows greater flexibility in incorporating built-in test (BIT) features through the inclusion of coupling circuits and diode detectors which provide DC voltages at test points as an indication of RF functionality. Hence, this technique may be used to minimize the time required for troubleshooting and replacement at the modular level.

Problem areas to be avoided include poor design/construction practices concerning the establishment of a uniform RF groundplane beneath the MIC substrate and the use of miniature RF connections lacking captivated center-pins. Where Class C microwave transistors are used to achieve RF power levels greater than five watts, the use of partially internally-impedance-matched devices reduces circuit design and manufacturing tuning problems significantly.

The MIC construction medium has propagating losses comparable with other planar and coaxial forms of microwave circuit construction. It is, however, limited with respect to achievable "Q" levels which make its use impractical in applications where the bandwidth must be restricted to less than approximately 2% and where a high degree of selectivity is required.

2. Surface Acoustice Wave (SAW) Device Technology

The emerging technology of Surface Acoustic Wave (SAW) devices presents many new opportunities in signal processing functions, implementation of correlation processes, bandpass filtering, and pulse expansion/compression applications. The following outline enumerates some of the device types currently in various stages of development throughout government and private industry, and the approximate level of performance expected in a post-1980 time frame.

a. Dispersive Delay Lines

(1) Linear/nonlinear FM

(2) Time bandwidth products up to 10,000
(3) Frequencies up to 1 GHz
(4) Sidelobe suppression 25-45 dB
(5) Insertion loss 15-40 dB

b. Bandpass Filters
(1) Frequencies up to 1 GHz
(2) Bandwidth 1%-50%
(3) Stopband rejection 50 dB
(4) Insertion loss 10-20 dB
(5) Phase linearity within 1^{o}-2^{o}

c. Nondispersive Delay Lines
(1) Frequencies up to 1 GHz
(2) Bandwidth 1%-50%
(3) Maximum delay 6-100 μsec
(4) Delay accuracy less than 1 nsec
(5) Up to 200 taps

d. SAW Resonators
(1) Effective Q 500 to 25,000
(2) Maximum bandwidth 1%
(3) Frequencies 30 MHz to 1.5 GHz
(4) Temperature Stability $\pm$ 0.01% from $-20^{o}C$ to $+50^{o}C$

e. SAW Oscillators
(1) Frequency range 10 MHz to 1.5 GHz
(2) Maximum FM deviation 1%
(3) Temperature Stability 0.01% from $-20^{o}C$ to $+50^{o}C$

The development of SAW devices and the associated maturity of the SAW technology faces problems such as mass loading effects, interelectrode reflections, acoustic diffraction and beam steering effects and other second-order phenomena which alter the amplitude and phase profiles of propagating acoustic waves and limit sidelobe suppression performance. The current evolution of this technology is based primarily on the development of better mathematical modeling and computer aided synthesis techniques with empirical verification of second-order effects and the inclusion of appropriate compensations.

In general, the inherent reliability of SAW devices should be superior to conventional lumped-element construction. The lack of discrete elements and extremely fine physical dimensions inherent in SAW device construction also precludes all but rudimentary input-output testing at the O-level. The relatively low cost of these devices, however, makes replacement on a modular basis an acceptable approach for maintainability.

K. STANDARD AVIONICS MODULES

1. Problem Statement

The proliferation of packaging concepts used in military equipment limits the ability to achieve the reliability and maintainability required to achieve the desired level of combat effectiveness. In addition to aggravating the maintenance and logistics posture, the use of a new or different packaging approach for each new system results in deployment of an unproven or immature design exhibiting poor reliability.

2. Problem Solution

The Standard Avionics Module (SAM) Development and Implementation Program Plan proposed to AIR-360G is aimed at solving this problem through development of standard modules with functions which are common to a large number of avionics subsystems using an approach similar to the present Standard Electronic Modules (SEM) program but having higher density packaging.

By controlling the module mechanical, electrical and thermal interfaces and having common functions, the number of module types can be reduced to where the necessary detailed design review, qualification and quality assurance can be placed on the modules to achieve reliable and mature designs at the module level. This is then reflected in higher system reliability by controlling the module thermal interface and using high reliability, mature back panel interconnections.

3. Risk

The SAM program has scheduled a demonstration system completion for late FY 1979. An AWAAS could be one of the first major systems to apply the concepts of SAM to an aircraft. Therefore, the number of existing standard functions will be limited. This could lead to additional front end costs for developing new functions and for their qualification.

4. Risk Avoidance

The SAM program should not in itself impose new and untried packaging technology. Built into the SAM/SEM programs are escape clauses which permit system and program manager decisions to allow special functions and different packaging where it is demonstrated they have less risk, lower life cycle cost (LCC), improved performance, or needed size and weight benefits.

An aggressive development of SAM during the next five years will reduce any potential risks.

5. General Discussion of SAM

The use of SAM should not in itself impose any new technology requirement. SAM technology may be different in detail than that with which a supplier is familiar. However, these differences will probably cause problems that are minor compared to difficulties which the supplier will face if he does not control, or if he deliberately changes, his packaging designs.

SAM consists of taking an existing packaging technology that is compatible with high density packaging and defining the electrical, thermal, and mechanical interfaces for modules which will have a broad range of mechanical and functional commonality. SAM will not deviate greatly from the mainstream of current avionics packaging. The size of currently proposed SAM modules is one-half the size of an Air Transportable Rack (ATR) enclosure (approximately 3" x 6" board area). This size appears to be a reasonable compromise between the costly 6" x 9" module size and a smaller inexpensive size with greater functional commonality.

L. BIT/BITE/DESIGNED-IN TESTABILITY

There are a number of major identifiable trends active at the present time in the generalized areas of equipment maintenance support and built-in test. The motive forces driving these trends, the high costs and the high skill levels required for maintaining complex equipment, are not decreasing in severity. On the contrary, it seems reasonable to project the trends as continuing to gain in momentum, at least for the immediate future. Whether these are only trends or whether they represent evolutionary changes remains to be seen, although the latter appears to be the case from the present perspective. In the subsequent disscussion, these trends, the individual dominant forces behind them, and their current positions are reviewed. Following this, their implications relevant to an AWAAS system are discussed.

One of the more visible trends is toward integrated testing (BIT, BITE, etc.) to support on-site, or organization, level maintenance. The ideal goal is a totally self-tested system that prompts its own repair action and reduces maintanance operator requirements to purely mechanical functions. Unfortunately, if this is considered to be the ultimate desired goal, then the current state of the art can at best be described as primitive. Proven methodologies for effectively applying the concept of integrated testing do not exist except for a very small number of design and technological environments. Even the digital electronics field, which out of necessity has been the focal point of the bulk of integrated test development efforts, has resisted the formation of an effective integrated testing methodology. There do not even exist accepted conventions for specifying the form, capability or operational evaluation of integrated testing.

Another visible and significant trend, both in the commercial world and in the military, has been a movement toward standardized and flexible test equipment. This represents an apparent reaction to the mass of diverse, sophisticated, specialized and expensive test equipment that has come into existence to support a broad spectrum of different equipment designs. Further, the effectiveness of this mass of dedicated test systems has not been totally satisfactory. A significant contributor to deficiencies in this area has been the approach whereby systems have been designed without regard to truly realistic testing requirements. This is followed by independent attempts to design specialized test units that will carry the total burden of the testing needs. To a great extent, the current effort to design for testability has been a response to this situation.

Efforts to standardize test equipment have proceeded in two definite and complementary directions. The first of these is toward large programmable test systems that can accommodate an extensive assortment of testing requirements (e.g., VAST). The second has amounted to the refinement of conventional, general-purpose test equipment, such as oscilloscopes and logic analyzers, coupled with the purposeful design of application systems for maintenance with this equipment (design for testability). It appears at this time that the two approaches are developing in parallel with each evolving to dominate its own sphere of effectiveness.

The large tester approach has proven very effective for testing small modular circuits and individual devices. Electronics components and devices are frequently tested in large volumes at centralized locations, both within vendor houses and at vendor-customer interfaces. Investment in expensive machines is warranted at such locations, where the usage factor is high, the actual number of machines is small, and the built-in flexibility ensures a long service life.

The general-purpose test equipment/design for testability approach has arisen from a different, to some degree oppositely polarized, set of considerations. Military system unavailability is costly. The sphere of effectiveness, in this case, is the military system, located in its operating environment. First, the test equipment must be immediately available at or near the operational site of the weapon system, therefore it must exist in large numbers. If it is not single system-dedicated, its usage factor will probably be high. Furthermore, if the usage factor is high, the equipment is more economically attractive and maintaining operator skill is less difficult. Second, the large and sophisticated general test systems have historically demonstrated the same ineffectiveness for handling complete weapon systems/subsystems as the dedicated test systems cited above, presumably for much the same reasons. At some threshold, the complexity of a total weapon system overwhelms the capacity of any fully external test instrumentation, dedicated or general, for achieving unaided performance analysis. Third, the totally self-contained integrated testing concept has not yet approached the level of maturity at which it can reasonably be expected to assume the full burden of maintenance testing.

The general-purpose test equipment/design for testability with some built-in test capability approach, represents a practical compromise between total self-supported and total externally-implemented maintenance testing. It is available when fully integrated testing cannot practically be implemented. At the same time, it circumvents the cost impact of utilizing large numbers of dedicated test units or major test systems (which must themselves be maintained).

One major additional trend that is significant is a growing general interest in fault-tolerant designs. Until very recently, this did not receive serious attention outside space-related programs, telephone switching networks, and similar specialized and critical areas. Generally good results were returned where fault-tolerance was applied, but its widespread application was impeded by the cost of its development, the lack of skilled practitioners and the cost impact of its implementation. The availability of complex, low-cost LSI functions has somewhat relieved the implementation cost problem, at least for digital systems. This is the apparent driving force behind the currently increasing level of interest. The cost of development and the lack of skilled practitioners are unresolved problems at this time, and will remain so into the early 1980's.

A very attractive aspect of fault-tolerant design is the potential for achieving a high degree of self-test capability. Self-testing is inherently performed, at least in a virtual sense, in all fault-tolerant configurations. It remains as primarily a state observation problem to interpret the system condition in terms of required maintenance action.

The foregoing discussion has described the general atmosphere in which an AWAAS would be developed. Many promising maintenance philosophies have come, some have gone, and none stand as truly proven. Several trends are discernible in the overall progress of system maintenance, but the point in time where any kind of stabilization of these trends may be reached and the corresponding form of approach that may be followed are not evident. Based upon the momentum behind the trends, however, it seems reasonable to project them into the near future in the context of an AWAAS development time frame.

It appears that the developing overall philosophy for maintenance testing implementation is an ordered application of the following approaches:

a. Integrated testing (i.e., built-in testing),
b. GP test equipment/design for testability,

c. System-dedicated test equipment/design for testability, and

d. Large test system/special test equipment

The levels of application of these approaches and the related maintenance actions are shown in Table 1. The above list essentially represents an order of preference moderated by a realistic expecion of effectiveness. As such, it is more useful to view the implementations in a complementary, rather than a competitive, sense. In what follows, the application and risk associated with each maintanance testing implementation are considered.

Table 1. Maintenance Testing Implementation

MILITARY ACTIVITY LEVEL OF MAINTENANCE	TEST IMPLEMENTATION APPROACH	EQUIPMENT LEVEL OF MAINTENANCE	MAINTENANCE ACTION
O	a-b-c	WRA-SRA	Restore Equipment Operation
I	a-b-c	WRA	*Repair/ Restore Equipment Operation
		SRA	Return to Depot or Discard
D	d	SRA	*Repair or Discard

* Repair implies action other than equipment adjustment or replacement.

Integrated testing, or self-testing, is the most desirable form of system maintenance testing from strictly a maintenance viewpoint. An effective BITE can significantly improve system availability and reduce repair costs by augmenting existing forms of organizational level testing. The operational performance monitoring aspects of integrated testing are in some cases attractive in their own right, in addition to the obvious maintenance benefits they provide. Application of integrated testing aimed at SRA level fault isolation has proven more consistently successful than that aimed only at WRA level testing. One possible reason for this comparative difference is that WRA level testing may frequently be selected as an economy measure and then under-designed. An SRA oriented configuration, on the other hand, tends to be applied with more detailed attention and with significant development and hardware investment expected.

Probably the most significant problems associated with the application of integrated testing are misapplication and performance specification, each of which can be interpreted in terms of risk. Some system and subsystem configurations are naturally compatible with full or partial built-in performance monitoring and/or fault isolation. Some, however, are not at all compatible. Attempting to force the integration of testing in such a case will likely result in a costly and ineffective configuration that may even have a negative maintainability impact. A more subtle case of misapplication arises when testing is integrated and very little useful maintenance information is actually gained. This situation may occur when malfunctions may readily be analyzed by already available alternate means, e.g., system status monitors, video display, etc.

Where apparently good candidates for integrated testing are identified, the specification of built-in test performance requires careful consideration. Overly stringent specifications will rapidly increase development and implementation costs. The level of complexity will also be increased with the possible result of a built-in test system that is less effective than one that is less stringently specified and less complex.

It should not be overlooked that integrated testing can be a significant aid to intermediate level maintenance. This actually overlaps the design for testability area, but it is an important motivation for integrated testing.

Where integrated testing is not suitable or must be supplemented, the most desirable approach is that of configuring the system for maintenance with general-purpose test equipment. This applies both at the organizational and at the intermediate levels. It should be noted here that the design for testability concept encompasses possibly significant integrated test hardware. In some areas, this may approach both the form and the cost of fully integrated testing. One challenge here appears to be the specification of an acceptable array of general usage test equipment upon which to base the design specifications. The greatest challenge, however, appears to be implementation of a management process for effectively assuring compliance with the testing concept throughout system development.

The next approach listed results from relaxing the requirement for strictly general-purpose test equipment and admitting system-dedicated test units. This is economically unattractive, as was previously noted, but it will be necessary in some instances. The problem here is to ensure that this direction is not taken unless it is essential.

The last approach on the list describes depot level activity. This is the point of repair or throwaway for SRA's. The effectiveness of activity at this level will mainly depend upon the efficiency of the O and I level activities for correctly identifying faulty SRA's. This function is indispensable, but it should not become a crutch for allowing deficiencies at the higher levels.

The impact of partitioning on the effectiveness of any maintenance testing approach is well known. A poor partitioning approach can itself severely dilute the effectiveness of the best testing methodology.

As such, this subject should be given particular attention in the context of testing requirements.

Since a common vocabulary does not exist, the program must itself establish a program level set of accepted definitions and understandings for establishing dialogue in the maintenance area. It is not so important that this be formal and all-encompassing as that it be consistent and unambiguous. If this is neglected, effective dialogue will be difficult.

Also, the maintenance aspect of configuration management should be stressed and a point of consultation and overall control for this specific area is recommended. A realistic maintenance plan should be incorporated into the initial system and subsystem studies and a coordinated operational effectiveness evaluation plan should be formed as early as is reasonable. Progress in the maintenance area should be included as an important subject at design reviews. Without this overall control, uniform success in the system maintenance implementation would be doubtful.

In summary, the evolving approaches to maintainable systems are being driven by purposeful attempts at achieving effective organizational and intermediate level maintenance, with particular emphasis on the former. The potential benefits, both in cost and in equipment availability, have been established. The necessity of at least not further increasing the demands upon maintenance operator skill levels and of reducing the mass of costly, difficult-to-maintain, and often ineffective special test equipment is repeatedly cited. It appears that the current trends have the potential for achieving this. The fact is significant that they are developing in a practical sense with the awareness that maintainability should be treated as a controllable system design parameter.

M. NAVIGATION SYSTEMS

Presently, all aircraft having inertial navigation systems require gimballed platforms on which gyroscopes and accelerometers are mounted. These stable elements are maintained in a local level coordinate frame so that accelerometer outputs represent vehicle translational motion. An alternate approach is to mount the accelerometers and gyros directly to the airframe ("strapdown" configuration) and compute the vehicle motion by transforming the sensor outputs into the local level frame. This approach is desirable because it eliminates the mechanical and electrical components associated with the platform (e.g., gimbals, gimbal bearings, torque motors, angle resolvers, slip rings, tachometers, and platform stabilization electronics). Implementation of the strapdown Inertial Navigation System (INS) has awaited the development of high speed computers and rugged accelerometers and gyroscopes having moderately high accuracy over a wide dynamic range.

The advent of high speed digital computers has made possible the rapid coordinate transformations required to process accelerometer outputs. Also, the technology of small, rugged accelerometers capable of operating in a high vibration, high gee environment is now available. The main high risk element has been the development of a gyroscope capable of operating in the airframe environment.

The technological advances in inertial navigation systems during the next five years are going to be limited to improvement and validation of existing system concepts. Two systems will be candidates for an AWAAS development:

a. F-18 CAINS 1A (AN/ASN-130 technology)
b. Ring Laser Gyro (RLG) strapdown system

The CAINS 1A inertial system includes a miniature dry gyro with inherently poor warmup characteristics. Weight reduction is neither anticipated nor required beyond the AN/ASN-130. There may be some improvement in the system component errors, but no breakthrough is expected to improve system performance during warmup. The AN/ASN-130 will not provide a substantial enhancement in system readiness over the existing AN/ASN-92.

Though there are promising spinning mass gyros (e.g., the electrostatically suspended gyro) being developed for strapdown application, the most novel approach is the Ring Laser Gyro (RLG). The RLG system at this time seems to represent the most ideal candidate for the navigation system of an AWAAS. Because of the lack of moving parts, the RLG has some important advantages over a spinning mass gyro. These advantages include greater ruggedness, wider dynamic range, more rapid reaction time, inherently digital output, insensitivity to high gee loading and vibration, higher angular rates, and instantaneous warmup. The RLG requires no precision machined parts and may be capable of automated production, resulting in lower cost. Finally, the projected lifetime of RLG's exceeds 100,000 hours. However, the RLG system alignment (carrier and ground) and navigation accuracy in various types of aircraft must be demonstrated. At the present time, the Navy has programs underway to validate the capability of a strapdown RLG inertial system as a possible alternative to both the AN/ASN-92 and the AN/ASN-130 Inertial Measuring Units (IMU's). The RLG/CAINS test program is scheduled to be completed by the end of 1978. By 1980, the Navy should have enough data on hand to assess performance, reliability, maintainability, life cycle cost, etc. of both the AN/ASN-130 IMU and the RLG IMU.

At the present, it is very clear that the RLG system has distinct and appealing advantages over the AN/ASN-130 IMU for the following fundamental reasons:

a. Alignment time is almost independent of initial system ambient temperature.

b. System calibration stability is expected to exceed the nine month period of carrier deployment. This would eliminate the existing I level on-board hardware for system calibration.

c. The MTBF is expected to be at least ten times that of the AN/ASN-130 or the AN/ASN-92 IMU.

d. Lower overall life cycle cost is virtually assured.

It must still be demonstrated that the RLG system navigation performance is comparable with that of the AN/ASN-92. After this is demonstrated, then the RLG IMU should be considered the candidate system for an AWAAS.

The system in-flight position update should be accomplished by the Global Positioning System (GPS). If the GPS does not become operational, then the Omega System might be a better alternative than the present Transit.

The catapult alignment will not provide acceptable accuracy. In the F-14, it has been replaced by "stored heading" alignment. The stored heading mode is in all CAINS systems, including F-18. Catapult alignment should not be a part of any AWAAS Operational Requirement.

The most crucial aspect of an AWAAS navigation system alignment, as in CAINS, will be the interface with the SINS. The data link is not secure, and the alignment data now transmitted is not in an optimal format. More specifically, some of the areas which need to be studied, analyzed, and improved upon are as follows:

a. Development of a "secure" data link for transmission of SINS data,

b. Optimization of SINS data link transmission format,

c. Provision for a back-up system for the SINS reference,

d. Optimization of SINS processing for CAINS alignment reference data,

e. Data link transmission of additional parameters of importance,

f. Development of a telemetry system on the carrier between the aircraft and the bridge using a computer and display system to monitor aircraft system status, BIT, etc., and

g. Integration of GPS/Omega/SINS to generate a pseudo differential Omega for aircraft equipped with the Omega system.

N. AIRCRAFT ELECTRICAL POWER SYSTEMS

The trend in aircraft electrical power systems is toward all solid state power conversion and power switching, which results in the elimination of electromechanical relays and switches, and bulky power line frequency transformers. The driving forces for these approaches are reduced size and weight, improved reliability and performance, lower cost, and programmable digitally-controlled power management.

Utilization equipments will be using, for the most part, switching power supplies which operate from either 115/200 V rms, 3-phase, 400 hertz AC or 270 VDC input power. In the 1980-1990 time frame, a family of military qualified power supplies will be avilable from multiple industry sources that will provide a number of standard voltage/current ratings in Standard Electronic Module (SEM) and Standard Avionics Module (SAM) package configurations.

The Advanced Aircraft Electrical System (AAES) program, which is managed by Naval Air Development Center (NAVAIRDEVCEN), Warminster, Pennsylvania, is directed toward the development of an integrated electric power generation, power management, and data transmission system utilizing a family of standard modules that an aircraft designer can incorporate into any new airframe. The AAES consists of a power generation subsystem (PGS), a solid state electric logic (SOSTEL) power management subsystem, and a general purpose multiplex system (GPMS) data transfer system. Electric power generation is via a high voltage (270 VDC) dc generator. The 270 VDC is converted to user voltage levels by solid state dc-to-dc and dc-to-ac regulated converters. The 270 VDC generators and bus switching are to be connected to the power bus through hybrid (solid state and electromechanical) bus contactors (BC). Power to individual loads from the 270 VDC bus are to be connected through remote power controllers (RPCs), solid state switches, and protection devices.

The RPCs are commanded by logic level signals from the SOSTEL control group. SOSTEL terminals located throughout the airframe accept logic level signals from a variety of switches, sensors, transducers, etc. These signals are transmitted to a central processor where they become factors in the solution of Boolean equations stored in the processor's memory. The resulting logic products are transmitted to other terminals to be translated into command signals for the power controllers. The terminals of the SOSTEL are tied together by the GPMS data buses. These buses also provide the medium for avionics data transfer. The operational program stored in the processor allows the SOSTEL to not only perform normal load management but also shed or transfer loads in the event of power degradation.

The AAES contains within its operational structure a BIT (Built-In-Test) facility which allows quick identification of unit failures by the central processor. This information is readily accessed by the flight crew or the maintenance crew. Redundancy and automatic reconfiguration allows the system to continue operation even in the event of several discrete failures. Any radical change in the power system design, which requires a whole new set of 270 VDC equipments and components, e.g., High Voltage Direct Current (HIVDC) generators, inverters, brushless DC motors, remote power controllers, and contactors, entails some risk due to the development of new equipments and components which will use solid state high voltage and high current devices. This risk is reduced by developing good designs, and by conducting adequate electrical, environmental and flight tests prior to fleet use.

Electromagnetic interference (EMI) problems could arise by configuring a total aircraft based upon switching power supplies. Adequate EMI specifications should be adhered to and the necessary qualification tests performed on the equipments comprising the aircraft electrical power system.

Maintenance problems which arise from a lack of availability of replacement components or equipments are a very real risk in new technology areas. Thus, it is important to develop reputable second sources for all new components and equipments.

There is still some controversy on the subject of personnel safety on aircraft using the 270 VDC HIVDC system. This personnel safety question will not be resolved until field experience is gained with the 270 VDC HIVDC system. A disadvantage of HIVDC is the difficulty of interrupting an arc once it has started, causing potential wire failures or fires in a combustible atmosphere. Alternating current (AC) arcs tend to be self-extinguishing. Very rapid fault control is required for the HIVDC system.

One problem associated with AC or DC solid state power switch controllers is the concentrated power dissipation which results from the voltage drop across solid state devices in their ON state. The requirement for small package size increases this thermal problem. Thus, prime importance should be placed on the thermal interfaces of the solid state power controllers and hybrid contactors.

From a circuit design standpoint, the aircraft electrical system will be more complex because solid state circuitry will be replacing electromechanical switches, contactors, power line frequency magnetics, and additional SOSTEL digital circuitry will be introduced for power management control. This implies that power system testing and troubleshooting will become more difficult. However, with SOSTEL digital control already incorporated, it would probably be advisable to incorporate BIT to monitor and diagnose failures in the aircraft electrical power system. Consideration should also be given to including the utilization equipment power supplies within the umbrella of this BIT system. However, one problem that immediately arises is that some independent source or backup source of BITE power is required since a loss of normal power means that the electrical system BITE capability is lost at the most critical time.

III. GENERAL DISCUSSION

A. RELIABILITY AND MAINTAINABILITY CONSIDERATIONS

System readiness encompasses consideration of the operational availability of an all-up system in the Fleet and, thus, consideration of system reliability and maintainability (R&M). The viewpoint thus far provided has been that of a technological forecast, that is, a synopsis of evolving technologies and their corresponding impact on system readiness in terms of potential risks or potential risk avoidance.

It is worthwhile at this point to clarify the usage of such terms as reliability, maintainability, and availability. Also, specific concepts intended to enhance system readiness through improved reliability and maintainability will be provided, with attention to those trade-offs essential for maintaining compatibility between system availability and system life cycle cost.

Reliability is quantitatively expressed in terms of system Mean Time Between Failures (MTBF), the mean time, in hours, that an equipment or system will operate satisfactorily, i.e., pass all operational performance tests from restoration after a previous failure to the next failure. Quantitatively expressed,

$$MTBF = \frac{\text{Total Operating Hours}}{\text{Number of Failures}}$$

Maintainability is quantitatively expressed in terms of system Mean Time to Repair (MTTR), the mean repair time, in hours, required to diagnose a failure, isolate the failed item(s), restore the equipment or system, and test to check for operationally-ready condition. Note that this does not specifically identify costs related to logistic support as a measure of maintainability, but such costs must of necessity be considered in the development of an AWAAS maintenance philosophy as manifested in a Maintainability Control Program.

Availability of a system is defined as the probability that, at any given time, the system will be in an operationally-ready status, capable of performing in accordance with its specification during the next scheduled mission. Availability is a function of reliability and maintainability as expressed in terms of system MTBF and MTTR,

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF+MTTR}}$$

Clearly, as MTBF is maximized and MTTR is minimized, the expression for Availability approaches unity (100% availability).

Reliability and maintainability thus determine system availability and, hence, system readiness. To achieve acceptable reliability and maintainability commensurate with the desired availability, it is necessary to recognize and apply the philosophy that reliability and maintainability are quantitative parameters which must be considered on an equal basis with other design parameters.

B. RELIABILITY AND MAINTAINABILITY CONTROL

Reliability and Maintainability, as quantified by MTBF and MTTR parameters, are not independent of considerations of logistic support and life cycle cost. There are many trade-offs to be evaluated to maintain a realistic balance between system readiness and associated costs. To facilitate orderly trade-off evaluations and to ensure that system readiness technology risks are minimized prior to being "locked in" to a system design, it is necessary that strictly managed Reliability and Maintainability Control Programs be adhered to from system development through production.

The reliability Control Program is essential to the successful achievement of the reliability goals for an AWAAS and to ensure that risk areas in new and evolving technologies are minimized.

The program should contain milestones in accordance with the philosophy of MIL-STD-785. The requirements of AR-104 should also be used in the development of the program. In addition, the use of a reliability type of life test as a development tool during the design stages rather than restricting this type of testing to a post-development assessment function is necessary if the goal of substantial reliability improvement is to be met. It must be realized that adoption of this philosophy also means sanction of the building of duplicate development hardware in order that the life testing can proceed concurrently with the other evaluations normally imposed on development (ADM, EDM, and prototype) equipments.

The Reliability Control Program should minimally include the following elements:

a. Stress analysis of all circuits at each phase of design and development in order to reduce any inherent weakness of a given circuit,

b. Development of uniform Derating Criteria to ensure selection of components capable of operation in the equipment environment,

c. Worst-case analysis of all circuits to determine how a given circuit may function under worst-case conditions of input and output,

d. Sneak circuit analysis used as early as possible during design in order to determine if there are any possible failure paths which have inadvertently been designed into the equipment,

e. Reliability predictions based on MIL-STD-756 and MIL-HDBK-217B, and continually updated as the design evolves to estimate achievement of reliability goals,

f. Reliability allocations established from the top down so that each component, circuit, module, subsystem, system, and avionics package will have its own reliability goal to be used in design, selection, and procurement,

g. Failure modes and effects analysis conducted to determine the effects on system operation of a given failure mode which would be generated either from within or outside of the system, and

h. Design reviews at all phases of development with particular regard to the achieved or predicted reliability at the time of each review relative to the established goals.

The ultimate control of the Reliability Program should be the reliability test conducted in accordance with MIL-STD-781. This test will determine the reliability base line of the design and provide a departure point for reliability development testing in accordance with AR-104.

The Maintainability Control Program is essential to the successful achievement of the maintainability goals for an AWAAS and to ensure that maintenance risk areas in new and evolving technologies are minimized. Additionally, maintenance enhancement through incorporation of new self-test technology and modular design concepts should be fostered.

The program should contain milestones in accordance with the philosophy of MIL-STD-470. The requirements of AR-10 should also be used in the development of the program. The maintainability demonstration conducted in accordance with MIL-STD-471 provides the ultimate control for maintainability. The demonstration should minimally provide the following information:

a. Identification of any potential maintenance problems,

b. Demonstration of MTTR, and

c. Collection of pertinent data for further development of equipment procedures for troubleshooting and repair.

The primary means of control will be the use of design reviews at all phases of development with particular regard to the achieved-as-predicted maintainability at the time of each review relative to the established goals and maintainability predictions based on MIL-HDBK-472.

C. SYSTEM READINESS CONSIDERATIONS

There is growing concern over the problem that improvements in system reliability have not kept pace with improvements in system functional performance. There is also a growing concern over the rapidly increasing cost of maintenance. These factors have a severe impact on life cycle cost. In view of the trend toward increasing complexity and cost, it is necessary to address the following system readiness issues:

a. There is a demand for increased system performance and complexity which impacts system R&M.

b. The increased use of microelectronics, system modularity, and standard subsystems, which yield potential savings in maintenance man hour costs, will cause a shift in R&D costs from the support phase (back end) of a system life cycle to the design and development phase (front end).

c. When advantageous to the government, commercially available parts could be considered instead of military qualified parts.

d. Protection of proprietary processes and materials is sometimes a handicap in a procurement atmosphere that demands multiple source competitive development.

e. Early "lock in" to a specific design or an immature technology has frequently prevented utilization of more mature design and technologies throughout the life cycle of a system.

f. Competition should be preserved throughout system development despite the presence of marketplace pressures and economic pressures for early source selection.

This abbreviated list gives indication of potential changes in the development, design, and procurement processes which could significantly enhance system readiness concurrent with a stabilization of life cycle cost.

There have been numerous suggestions for improvements in methods of dealing with the issues mentioned above. Many of these suggested concepts merit serious consideration in an AWAAS development program. A partial list of the more significant concepts follows:

a. Contractor warranties,

b. Use of standard subsystems where possible [e.g., the AN/AYK-14 computer, a Carrier Aircraft Inertial Navigation System (CAINS) compatible inertial navigation system, Standard Avionics Modules (SAM), etc.]

c. Specification of form, fit, function, interface, and environment requirements, but not of internal design [This philosophy is currently employed in the Standard Electronic Module (SEM) program.],

d. Determination of trade-offs between service-performed and contractor-performed maintenance and consideration of the corresponding maintenance activity level, and

e. Maintenance of competition in follow-on procurements to foster reliability improvements.

A comprehensive study of the problems and concepts briefly discussed above, as applied to military electronics, was carried out by the Institute for Defense Analyses, at the request of the Office of the Director of Defense Research and Engineering. This study is documented in IDA Report R-195, "Electronics X: A Study of Military Electronics with Particular Reference to Cost and Reliability."

D. SUMMARY

The unifying thread in the preceding discussions of technology risk areas as they effect system readiness is this: There is no easy escape from the substantial technical and financial burdens of maintaining system readiness. Progress and solutions to problems will be evolutionary, not revolutionary. But, still, the advances in capability that can be drawn upon in an AWAAS development are truly significant, and R&M burdens that now exist can be significantly reduced. Some of the major factors in achieving a significant reduction in R&M burdens can be summarized as follows:

a. Reduction of airframe EO, IR, and EM observables to increase survivability, decrease battle damage, and reduce power output requirements for all categories of countermeasures equipment,

b. Selection of mature technology,

c. Design of the system for testability,

d. Partitioning of hardware by functions to permit BIT,

e. Partitioning or modularization of software by function to minimize the effect of individual changes on the overall software package,

f. Adequate funding for and management attention to the entire spectrum of software development activities and firm adherence to proven, documented procedures,

g. Selective use of redundancy in such areas as data buses, digital processors, and BITE,

h. Use of BIT/BITE technology for fault detection and isolation,

i. Use of a standard family of avionics system modules (SAM) and recognition of the possibility that the resultant savings in maintenance man hours and maintenance equipment costs may substantially exceed the cost of throwaway modules,

j. Use of standard subsystems such as a standard avionics computer and a CAINS-compatible inertial navigation system,

k. Use of the commercial electronics technology base where possible,

l. Dedicated adherence to the requirements of proven R&M specifications and procedures, and

m. Use of innovative procurement procedures, warranties, etc.

IV. ACRONYMS AND ABBREVIATIONS

AAES	-	Advanced Aircraft Electrical System
AC	-	Alternating Current
A/D	-	Analog to Digital
ADM	-	Advanced Development Model
A/J	-	Anti-Jam
ALOFT	-	Airborne Light Optical Fiber Technology
ASO	-	Aviation Supply Office
ATE	-	Automatic Test Equipment
ATR	-	Air Transportable Rack
AWAAS	-	All Weather Attack Avionics System
BC	-	Bus Contactors
BIT	-	Built-In Test
BITE	-	Built-In Test Equipment
CAINS	-	Carrier Alignment Inertial Navigation System
CCD	-	Charge Coupled Device
CFA	-	Cognizant Field Activity
CID	-	Charge Injection Device
CMOS	-	Complimentary Metal Oxide Semiconductor
CRT	-	Cathode Ray Tube
DA	-	Design Automation
DARPA	-	Defense Advanced Research Projects Agency
DC	-	Direct Current
DoD	-	Department of Defense
DSPN	-	Direct Sequence Pseudo Noise
ECL	-	Emitter Coupled Logic
EDM	-	Engineering Development Model
EMI	-	Electromagnetic Interference
EO	-	Electro-optics
FDM	-	Frequency Division Multiplexing
FLIR	-	Forward Looking Infrared
FM	-	Frequency Modulation
GP	-	General Purpose

GPMS - General Purpose Multiplex System
GPS - Global Positioning System
HARM - High-velocity Anti-Radiation Missile
HIVDC - High Voltage Direct Current
I^2L - Integrated Injection Logic
ICNS - Integrated Control and Navigation System
IF - Intermediate Frequency
I Level - Intermediate Level
IMU - Inertial Measurement Unit
INS - Inertial Navigation System
IR - Infrared
IRCM - Infrared Countermeasures
J/S - Jamming to Signal
JSWDL - Joint Service Weapon Data Link
JTIDS - Joint Tactical Information Distribution System
KOPS - Kilo Operations Per Second
LAMPS - Light Airborne Multipurpose System
LCC - Life Cycle Cost
LED - Light Emitting Diode
LLLTV - Low Light Level Television
LSI - Large Scale Integration
MAAS - Multiple Array Avionics Systems
MIC - Microwave Integrated Circuitry
MOS - Metal Oxide Semiconductor
MSI - Medium Scale Integration
MTBF - Mean Time Between Failure
MTTR - Mean Time to Repair
NAC - Naval Avionics Center
NASMAC - Naval Air Systems Command Software Management Advisory Committee
NAVAIR - Naval Air Systems Command
NAVAIRDEVCEN - Naval Air Development Center
NMOS - N-channel Metal Oxide Semiconductor
NTDS - Navy Tactical Data System

OE	- Opto-Electronic
OIC	- Optical Integrated Circuit
O Level	- Organizational Level
PGS	- Power Generation Subsystem
PMOS	- P-channel Metal Oxide Semiconductor
PMTC	- Pacific Missile Test Center
PSI	- Pounds per Square Inch
R&D	- Research and Development
RF	- Radio Frequency
RLG	- Ring Laser Gyro
R&M	- Reliability and Maintainability
RPV	- Remotely Piloted Vehicle
R&S	- Reliability and Supportability
SAM	- Standard Avionics Module
SAW	- Surface Acoustic Wave
SEM	- Standard Electronic Module
Si-CMOS	- Silicon gate Complimentary Metal Oxide Semiconductor
Si-NMOS	- Silicon gate N-channel Metal Oxide Semiconductor
SINS	- Ship Inertial Navigation System
SLCMP	- Software Life Cycle Management Plan
S/N	- Signal to Noise
SOS	- Silicon on Sapphire
SOSTEL	- Solid State Electrical Logic
SRA	- System Replaceable Assembly
SSA	- Software Support Activity
SSI	- Small Scale Integration
TADSO	- Tactical Automated Data Systems Office
TCR	- Temperature Coefficient of Resistance
TDM	- Time Division Multiplexing
T&E	- Test and Evaluation
TRAM	- Target Recognition/Attack Multisensor
TTL	- Transistor-Transistor Logic

TV - Television
VAST - Versatile Avionics Shop Test
VDC - Volts Direct Current
WRA - Weapon Replaceable Assembly

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A broad assessment is made of the technological development required to improve the overall readiness of all weather attack avionic systems to be developed in the 1980-1990 time frame. The projected state-of-the-art in the post 1980 time frame is briefly outlined and the additional development required to achieve significant improvements in system readiness is summarized. Areas of technological risk are identified. Required development and anticipated risks in the following are described:

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